

## ANALYSIS OF 80KW GRID CONNECTED ROOFTOP SOLAR POWER PLANT USING SISIFO

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### ABSTRACT

*In grid connected rooftop solar PV system, the available rooftop area on buildings is used for setting up solar power plant. The DC power generated from solar photovoltaic (SPV) cells is converted to AC power by solar grid inverter, and is fed to the grid during day time. In night, when solar power is not sufficient, loads are served by drawing power from grid. In this paper, real time and Simulation analysis of 80KW solar photovoltaic roof top grid connected power plant at St. Peter's Engineering College, Hyderabad city is carried out using SISIFO PV simulation software. The real time meter readings of import side and export side of energy are recorded. The real time 80KW solar power plant at St. Peter's Engineering College, Hyderabad generates 401.6KWh per day and simulation results of DC energy output of PV module and AC energy output of inverter are presented. The DC wiring losses and performance ratio are calculated using SISIFO PV simulation software. The DC energy output of PV array is 161232.67Kwh/year and AC energy output of inverter is 153128.45 KWh/year.*

**KEYWORDS:** Capacity Factor, Peak Demand, Energy Yield, Solar Radiation & Wiring Losses

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### 1. INTRODUCTION

St. Peter's Engineering College, Hyderabad is located at latitude of 17.35°N and longitude of 78.45°E and at an elevation of 505m from sea level [6].

Electric utilities are finding it difficult to meet the rise in peak demand and as a result, most of cities and towns are facing severe electricity shortages [5]. It is proposed to achieve a minimum of 3000MW's of grid connected rooftop solar power plants in Telangana state by 2018.

### 2. ON - GRID SOLAR ROOF TOP POWER PLANTS

Solar Photovoltaic cells convert sunlight energy to DC current through a photovoltaic process. The solar PV systems may be: off-grid and on-grid. Batteries are needed in off-grid plants [1]. Batteries require replacement once in every 3-5 years in off-grid.

In Grid connected solar rooftop power plant, the DC power generated from solar photovoltaic (SPV) panel is converted to AC power using solar grid inverter and is fed to the grid either of 11KV lines or of 400/230V, three / single phase lines, and if any shortfall of solar energy is imported from grid[2]. A schematic diagram of a grid connected solar rooftop photovoltaic power plant is shown in Figure 1 [3].

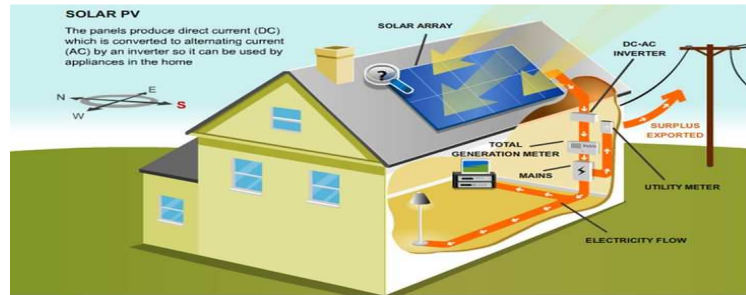


Figure 1: A Schematic Diagram of a Grid Connected Solar Rooftop Photo Voltaic Power Plant

### 3. SOLAR PANEL CHARACTERSTICS

The typical I-V curve and P-V curve for a solar panel are shown in Figure 2 [3]

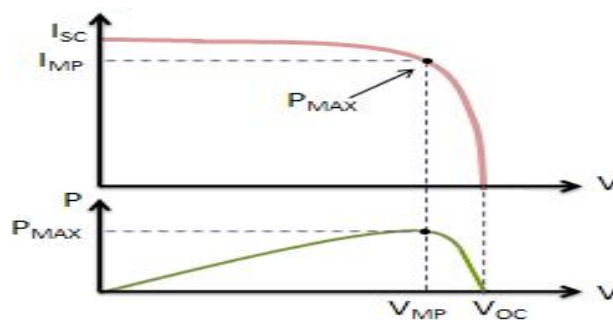


Figure 2: P-V and I-V Curve of a Solar Cell at a Particular Temperature & Irradiation

In the above figure, the Knee point is called “maximum power point” (MPP) [4]. In the curve,  $I_{SC}$  is the solar panel circuit current in short circuit condition &  $V_{OC}$  is the solar panel circuit voltage under open circuit condition.

$I_{MP}$  and  $V_{MP}$  are those of tracking point for maximum current and maximum voltage respectively, and can be tracked by MPPT system. Thus, the multiplication of both  $I_{MP}$  and  $V_{MP}$  gives the condition of maximum power for solar module as

$$P_{MAX} = V_{MP} * I_{MP} \text{ watt}$$

### 4. COMPONENTS OF SOLAR PV SYSTEM

A Grid-connected solar PV system consists of following main components [9]:

#### 4.1 Solar Photovoltaic (PV) Modules

Solar Photovoltaic modules are mounted on the roof of any buildings and convert sunlight energy into direct current. The size of a solar PV system depends on the 90% energy consumption of the building and the shade-free rooftop area available. Photovoltaic modules are formed with an array to get required voltage and current.

#### 4.2 Solar PV Array Support Structure

Solar PV array support structure consists of galvanized steel structures secure the solar PV modules on the roof of any buildings.

### 4.3 Solar Grid Inverter

Solar grid inverter tied PV systems consist of solar panels and a grid-tie inverter, with no batteries. The solar panels feed a special inverter known as Solar grid inverter, which converts the DC voltage coming from the solar panels directly into AC power to match the grid.

### 4.4 Balance of System

Other components of solar rooftop power plant are cables, junction boxes, fuses etc. The expected life of solar PV plant is 25 years.

## 5. PERFORMANCE ANALYSIS OF PV SYSTEM

The performance parameters are developed by International Energy Agency [11] for analyzing the performance of solar PV grid interconnected system.

### 5.1. System Parameters [7]

#### 5.1.1 Array Yield

It is equal to the time from which, the Photovoltaic plant has to operate with nominal solar generator power  $P_o$  to generate array DC energy  $E_A$ . Its units are kW h/d\* kWp.

$$Y_A = E_A / P_o$$

Where, Array energy output per day  $E_A = I_{dc} * V_{dc} * t$  (kW h),

$I_{dc}$  = DC current (A)

$V_{dc}$  = DC voltage (V)

$P_o$  = Nominal Power at STC.

#### 5.1.2 Reference Yield

The reference yield is the total in-plane irradiance  $H$  divided by the Photovoltaic's reference irradiance  $G$ . It represents the under ideal conditions obtainable energy. If  $G$  equals  $1 \text{ kW/m}^2$ , then Yr is the number of peak sun hours or the solar radiation in units of kW h/m<sup>2</sup>. Its units are h/d.

$$Y_R = [kW \text{ h/m}^2] / 1 \text{ kW/m}^2$$

$$Y_R = H_t / G_o$$

Where,

$H_t$  = Total Horizontal irradiance on array plane (Wh/m<sup>2</sup>),  $G_o$  = Global irradiance at STC (W/m<sup>2</sup>).

#### 5.1.3 Final Yield

It is the annual, monthly or daily net AC energy output of the system divided by the peak power of the installed Photovoltaic array at standard test conditions of  $1000 \text{ W/m}^2$  solar irradiance and  $25^\circ\text{C}$  cell temperature. Its units are kW h/d\* kW p.

$$Y_F = E_{PV, AC} / P_{maxG, STC}$$

#### 5.1.4 Performance Ratio

The performance ratio is the final yield divided by the reference yield. Performance ratio can be defined as comparison of plant output compared to the output of the plant could have achieved by taking into account irradiation, panel temperature, availability of grid, size of the aperture area, nominal power output, temperature correction values.

$$PR = Y_F/Y_R.$$

#### 5.1.5 Capacity Utilization Factor

It is defined as real output of the plant compared to theoretical maximum output of the plant.

$$CUF = \text{Energy measured (kW h)} / (365 * 24 * \text{installed capacity of the plant}).$$

#### 5.1.6 Inverter Efficiency

The inverter efficiency appropriately called as conversion efficiency is given by the ratio of AC power generated by the inverter to the DC power generated by the PV array system. The instantaneous inverter efficiency is given by,

$$\eta_{inv} = P_{AC} / P_{DC}$$

#### 5.1.7 System Efficiency

The instantaneous daily system efficiency is given as PV module efficiency multiplied by inverter efficiency.

$$\eta_{sys, T} = \eta_{PV, T} * \eta_{inv, T}$$

#### 5.1.8 Energy Output or Energy Fed to Utility Grid

The energy generated by the PV system is the measure of energy across the inverter output terminals for every minute [9]. It is defined as the total daily monitored value of AC power output and the monthly AC energy generated.

### 5.2 Specific Plant Losses

Energy losses occur in various components in a grid connected SPV Power plant under real operating conditions. These losses are evaluated using the monitored data.

#### 5.2.1 Array Capture Losses ( $L_C$ )

These are of Two Types

##### 5.2.1.1 Thermal Capture Loss ( $L_{CT}$ )

Losses caused by cell temperature higher than 25 °C are called thermal losses. Thermal capture loss ( $L_{CT}$ ) is the difference between reference field and corrected reference field.

##### 5.2.1.2 Miscellaneous Capture Loss ( $L_{CM}$ )

Losses that are caused by wiring, string diodes, low irradiance, partial shadowing, mismatching, maximum power tracking errors, limitation through dust, losses generated by energy conduction in the photovoltaic modules

$$L_{CT} = Y_R - Y_{CR}$$

$$L_{CM} = Y_{CR} - Y_A$$

$$L_C = Y_R - Y_A$$

### 5.2.2 System Losses ( $L_S$ )

These losses are caused by inverter, conduction and losses of passive circuit elements.

$$L_S = Y_A - Y_F$$

## 6 REAL TIME SYSTEM DESIGN

The main target is to design and install 80KW solar rooftop solar power plant.

### 6.1 Key Facts of Solar Rooftop Power Plant

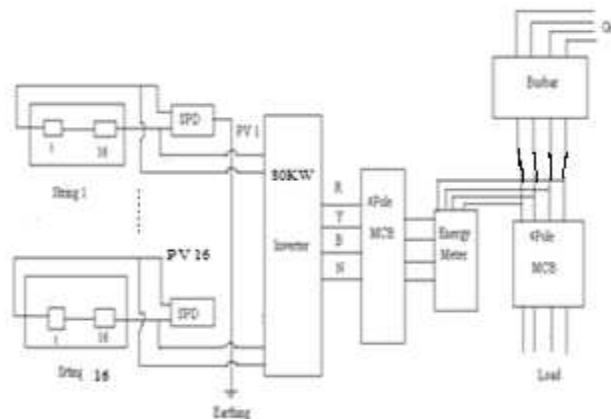
Plant capacity in KWp : 80KWp Rooftop Solar power plant

PV Technology/Module: Polycrystalline modules

Power conditioning unit: 80 KVA (30+30+20)

Power evacuation: 400/230V, three/single-phase, 50HZ

A typical Design of 80KW Solar Roof Top Power Plant of St. Peter's Engineering, Hyderabad city is shown in Figure 3.



**Figure 3: A Typical DESIGN of 80KW Roof Top Solar Power Plant at St. Peter's Engineering College, Hyderabad**

Actual on-site 80KW Solar Roof Top Power Plant of St. Peter's Engineering, Hyderabad city is shown in Figure 4.



**Figure 4: Actual Onsite of 80KW Solar Roof Top Plant at St. Peter's Engineering College, Hyderabad City**

## 6.2 System Capacity Based on Rooftop Area

Total Power output = Total area x Solar irradiance x Conversion efficiency

$$80000 = \text{Total area} \times 1000 \text{ Watts/m}^2 \times 0.1641$$

Total area required for 8KWp = 487 Sq. m = 5245 sq. feet

The rooftop area required to install 80KWp is around 5250 sq. feet.

## 6.3 Number of PV Panels for the System

Divide the total watt-hours per day needed from PV panels by the rated output watt-peak of PV modules.

Capacity of each module: 315Wp

Number of PV panels or modules required =  $80000\text{Wp} / 315\text{WP} = 254$

Number of strings as per system Design = 16 Numbers

Number of solar panels in each string = 16

The maximum power of this module is 315Wp; hence it requires nearly 256 modules to design 80KW PV system. The selected PV is manufactured by Vikram Solar and onsite arrangement of solar PV modules at St. Peter's Engineering College, Hyderabad City is shown in Figure 5.



**Figure 5: Actual Onsite of 80KW Solar Roof Top PV Modules at St. Peter's Engineering College, Hyderabad City**

The PV module parameters and ratings [5] are given in Table 1 and more specifications of PV module and dimension [14] are given in Table 2.

**Table 1: PV Module Parameters and Ratings**

| Electrical Characteristics  |         |
|-----------------------------|---------|
| Rated Maximum power (Pmax)  | 315Wp   |
| Maximum power voltage (Vmp) | 38.33 V |
| Maximum power current (Imp) | 8.22A   |
| Open circuit voltage (Voc)  | 46.04V  |
| Short circuit current (Isc) | 8.85A   |
| Module efficiency           | 16.41%  |
| Operating temperature       | 45°C    |

**Table 2: PV Module Specifications and Dimension**

| Specifications and Dimensions of PV module |                              |
|--|------------------------------|
| Solar cells                                | Poly crystalline solar cells |
| Solar cell size                            | 156 mmx156 mm(6 in x 6 in)   |
| Number of cells(pieces)                    | 72 (6 x 12)                  |
| Module dimensions                          | 1956mm x 992mm x 40mm        |
| Weight                                     | 27kg                         |
| Front glass                                | 4 mm tempered glass          |
| Frame                                      | Anodized aluminum alloy      |
| Protection degree                          | IP 65                        |
| High efficiency                            | 16.41%                       |
| Grid connection                            | ON/OFF grid                  |

#### 6.4 Solar Grid Inverter Rating

The solar array PV capacity is 80KW. The solar grid inverter requires will be in range of 76KW to 88KW. In solar grid connected plant, input rating of inverter should be same as PV array rating [13]. For this system, solar grid inverter used is 80KVA (30KVA+30KVA+20KVA) of Shenzhen Growatt New Energy Technology Co. Ltd make is shown in Figure 6.



**Figure 6: Actual Onsite 80KVA Solar Grid Inverter at St. Peter's Engineering College, Hyderabad City**

The inverter parameters are given in Table 3

**Table 3: Inverter Parameters**

| Inverter Specifications for 30KWp Inverter |                     |
|--|---------------------|
| Model Name                                 | Growatt 30000TL3-SE |
| Maximum DC voltage                         | 1000 d. c. V        |
| Maximum input current                      | 2*34 d. c. A        |
| Maximum apparent power                     | 33000VA             |
| Nominal output current                     | 3*34 a. c. A        |
| Nominal output voltage                     | 230V/400 a. c. V    |
| Inverter Specifications for 20KWp Inverter |                     |
| Model Name                                 | Growatt 20000UE     |
| Maximum DC voltage                         | 1000 d. c. V        |
| Maximum input current                      | 26/26 d. c. A       |
| Maximum apparent power                     | 20800VA             |
| Nominal output current                     | 32 a. c. A          |
| Nominal output voltage                     | 230V/400 a. c. V    |

### 6.5 Distribution Transformer Rating

The details of distribution transformer used in this Analysis is summarized as follows:

Location of Distributing Transformer: St. peter's Engineering College, Hyderabad city

Capacity of Distribution Transformer: 250KVA

The rating of SRTPV capacity = 80KWp

Total generating capacity in KWp = 80KWp

### 6.6 Feeder Rating

The details of feeder are summarized as follows:

Name of 11KV Feeder: St. Peter's Engineering College, Hyderabad city.

Feeder Number: CF

Name of 66 / 11 KV substation: Kompally, Hyderabad city

Type of conductor / cable (Size): Rabbit

### 6.7 Meter Specifications

The meter specifications are given below:

Meter Make: Secure meters Ltd.

Model No: Premier 300 Type E3M024, 3-phase, 4-wire

Meter Number (RR Number): RRN1458

Tariff: LT – 2

Sanctioned Load: 100 KW

## 7. REAL TIME TEST RESULTS

### 7.1 Meter Output Readings on Import and Export Side

The meter readings of energy meters are given in in Table 4.

**Table 4: Meter Reading on Import and Export Side**

| Date & Time     | Import Side |        |       |      | Export Side |        |       |       |
|-----------------|-------------|--------|-------|------|-------------|--------|-------|-------|
|                 | KWh         | KVAh   | KVArh | KVA  | KWh         | KVAh   | KVArh | KVA   |
| 18/12/17; 10:30 | 69.3        | 94.1   | 61.6  | 6.06 | 63.1        | 63.1   | 15.2  | 10.86 |
| 19/12/17; 12:30 | 110.3       | 135.9  | 64.8  | 6.06 | 97.6        | 98.7   | 18.6  | 12.7  |
| 19/12/17; 15:08 | 110.8       | 136.3  | 65    | 6.06 | 104         | 105.2  | 19.6  | 12.7  |
| 20/12/17; 15:30 | 146.8       | 173.1  | 66    | 6.06 | 128.8       | 130.8  | 22.5  | 12.12 |
| 29/12/17; 12:10 | 487.3       | 515.6  | 76.5  | 7.42 | 446.2       | 457.5  | 31.3  | 12.54 |
| 30/12/17; 15:45 | 524.8       | 553.2  | 76.8  | 4.06 | 502.5       | 514.7  | 32.2  | 12.54 |
| 25/01/18; 13:15 | 1605.2      | 1645.3 | 139.1 | 5.96 | 1323.9      | 1367.6 | 57.8  | 4.56  |



The energy at the import side on 18/12/17 at 10:30 is 69.3KWh & export side is 63.1KWh so the energy injected into grid is 63.1KWh.

The energy at the import side on 19/12/17 at 12:30 is 110.3 KWh & export side is 97.6 KWh so the energy injected into grid is 97.6 KWh. The energy at the import side on 19/12/17 at 15:08 is 110.8 KWh & export side is 104 KWh so the energy injected into grid is 104 KWh.

The energy at the import side on 20/12/17 at 15:30 is 146.8 KWh & export side is 128.8 KWh so the energy injected into grid is 128.8 KWh.

The energy at the import side on 29/12/17 at 12:10 is 487.3 KWh & export side is 446.2 KWh so the energy injected into grid is 446.2 KWh.

The energy at the import side on 30/12/17 at 15:45 is 524.8 KWh & export side is 502.5 KWh so the energy injected into grid is 502.5 KWh.

The energy at the import side on 25/01/18 at 13:15 is 1605.2 KWh & export side is 1323.9 KWh so the energy injected into grid is 1323.9 KWh.

The Energy output of three inverters from the actual site of 80KW solar roof top plant at St. Peter's Engineering College, Hyderabad as shown in Table 5.

**Table 5: Energy Output of Inverters**

| Date & Time    | Energy Output of 20 KVA Inverter in KWh | Energy Output of 30 KVA Inverter in KWh | Energy Output of 30 KVA Inverter in KWh | Total Energy Output from Three Inverters in KWh |
|----------------|---|---|---|---|
| 18/12/17 10:30 | 44                                      | 67                                      | 51                                      | 162   |
| 19/12/17 12:30 | 61                                      | 95                                      | 80                                      | 236   |
| 19/12/17 15:08 | 86                                      | 117                                     | 108                                     | 311   |
| 20/12/17 15:30 | 84                                      | 112                                     | 105                                     | 301   |
| 29/12/17 12:10 | 40                                      | 54                                      | 63                                      | 157   |
| 30/12/17 15:45 | 88                                      | 139                                     | 135                                     | 362   |
| 25/01/18 11:45 | 35                                      | 54                                      | 52                                      | 141   |

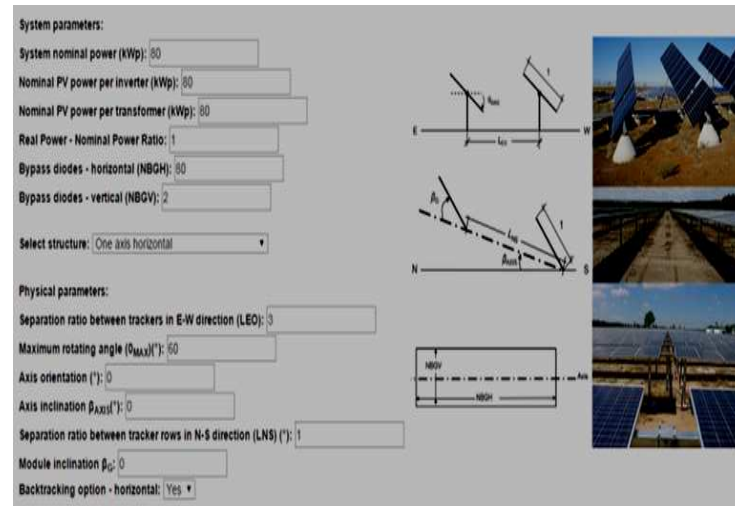
The total Energy output of all three inverters from the actual site of 80KW solar roof top plant at St. Peter's Engineering College, Hyderabad on 18/12/17 at 10:30 is 162 KWh, on 19/12/17 at 12:30 is 236 KWh, on 19/12/17 at 15:08 is 311KWh, on 20/12/17 at 15:30 is 301KWh, on 29/12/17 at 12:10 is 157 KWh, on 30/12/17 at 15:45 is 362KWh and on 25/01/18 at 11:45 is 141KWh.

## 8 SIMULATION ANALYSIS RESULTS USING SISIFO

SISIFO PV Simulation software [12] is one of the open web service for the simulation of solar power plants.

## 8.1 Resource Data and System info

The resource data and system info for inputs considered for 80KW roof top solar power plant are shown in Figure7

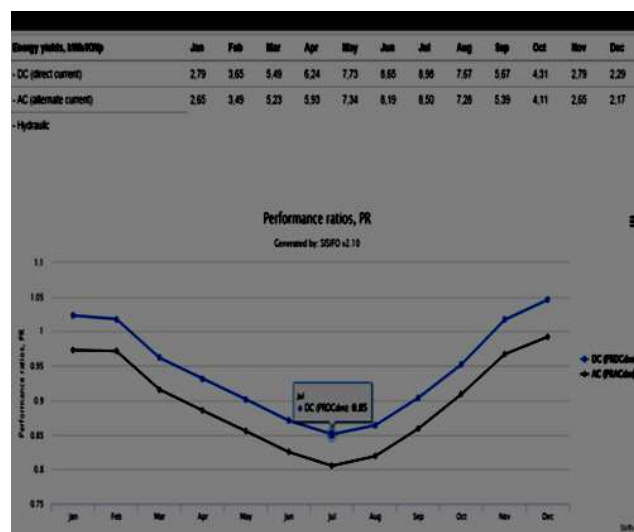


**Figure 7: Resource Data and System Info of 80KW Solar Rooftop Plant**

The system considered is DC system size 80KW, module array type is 1-axis horizontal tracking with tilt angle  $60^\circ$ .

## 8.2 Results of 80KW Rooftop Solar Plant

The maximum energy is generated in the month of July is 8.5 KWh/KWp and minimum energy generated in the month of Decis 2.17 KWh/KWp. The annual average AC energy yield is 5.244 KWh/KWp and annual average AC energy yield of 80KW plant is 419.53KWh/day and the annual average DC energy yield is 5.521KWh/KWp and annual average DC energy yield of 80KW plant is 441.73 KWh/day as shown in Figure 8.



**Figure 8: Simulation results**

The PV module specifications are given in Figure 9

Figure 9: PV Module Specifications

The solar cell material is Silicon-crystalline with only temperature effect module and operates at nominal cell temperature of 45<sup>0</sup>c.

The mean daily irradiation and temperature for different months are given in Figure 10 and Figure 11.

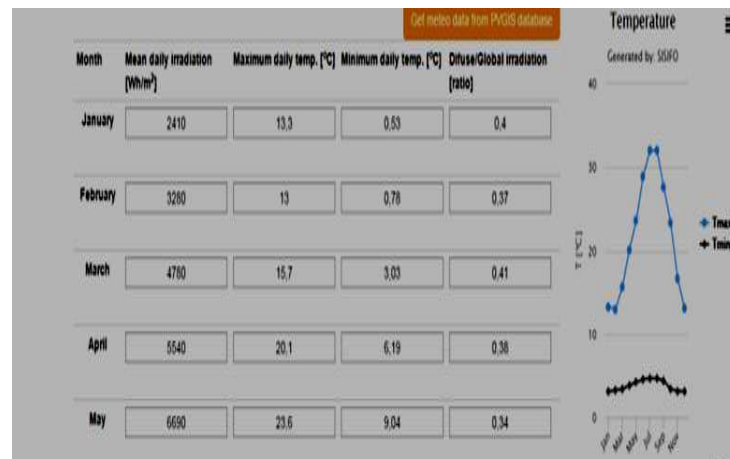


Figure 10: The Mean Daily Irradiation and Temperature From Jan- May Month



Figure 11: The Mean Daily Irradiation and Temperature from Jun- Dec Month

The inverter efficiency curve for different points are shown in Figure 12

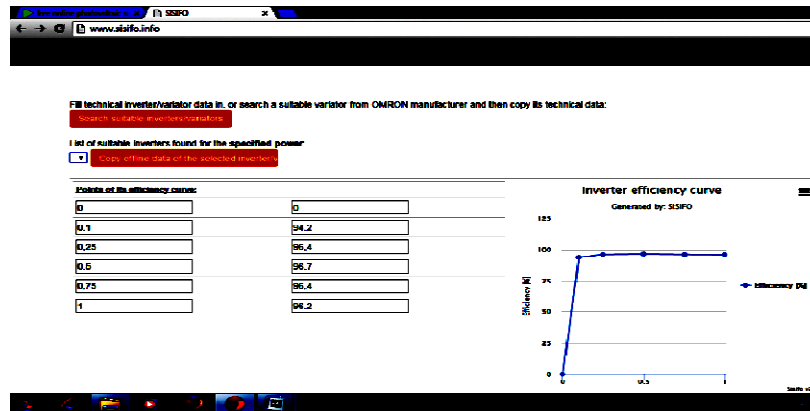


Figure 12: The Inverter Efficiency Curve

The wiring losses are given in Figure 13

The screenshot shows the "Wiring" section of the SISIFO software interface. It contains four input fields for different types of wiring losses:

| Wiring Loss Type   | Value (%) |
|--|-----------|
| DC wiring losses between PV generator and inverter (%)   | 1.5       |
| AC wiring losses between inverter and MV transformer (%) | 3         |
| AC wiring losses between MV and HV transformers (%)      | 0         |
| AC wiring losses between HV transformer and the PPC (%)  | 0         |

Figure 13: The Wiring Losses

The annual average solar radiation is  $4.88 \text{ kWh/m}^2/\text{day}$ . The solar energy incident on the solar panels will convert into electrical energy. The DC wiring losses between PV and inverter are 1.5%. After the inverter losses the available energy obtained at the inverter output is 153128.45 KWh /year and the DC output of array is 161232.67Kwh/year. The performance ratio is 0.8 as observed from Figure 8.

## 9. CONCLUSIONS

The real time design of an 80KW solar PV power plant located on the roof of a St. Peter's Engineering College building in Hyderabad city was carried out by means of determining the engineering standards and realistic constraints of design. The required shaded free roof top area for installing such plant is found to 5250 sft. We studied how to establish a real time design of 80KW photovoltaic solar roof top power plant, and the installation of the 80KW roof top plant and the meter readings are recorded.

A performance and Simulation analysis of 80KW peak grid connected solar photovoltaic power plant installed at Hyderabad was evaluated on annual basis using SISIFO PV Simulation software. The following conclusions are drawn from the study.

- The maximum energy is generated in the month of July is 8.5 KWh/KWp and minimum energy generated in the month of Decis 2.17 KWh/KWp.

- The annual average solar radiation is 4.88 kWh/m<sup>2</sup>/day. After the inverter losses the available energy obtained at the inverter output is 153128.45 KWh /year, and the DC output of array is 161232.67Kwh/year.
- DC wiring losses between PV and inverter are 1.5%, and the performance ratio is 0.8
- The energy at the import side on 20/12/17 at 15:30 is 146.8KWh & export side is 128.8KWh, so the energy injected into grid is 128. KWh.
- The energy at the import side on 30/12/17 at 15:45 is 524.8KWh & export side is 502.5KWh, so the energy injected into grid is 502. KWh.
- The energy at the import side on 25/01/18 at 13:15 is 1605.2KWh & export side is 1323.9KWh, so the energy injected into grid is 1323.9KWh
- The real time measured energy output of 80KW solar grid connected roof top power plant is 401.6KWh/day, and the simulation output of 80KW solar grid connected roof top power plant using SISIFO PV software is 419.53 KWh/day.

## REFERENCES

1. Jayanna Kanchikere, K. Kalyan kumar, "Proposal for 1 kW Roof-Top Solar PV Plant", *International Research Journal of Engineering and Technology (IRJET)*, Vol. 4, Issue 7, July2017
2. Manu Kumar D. M., Ganesha T., Mallikarjunayya C. Math, "Performance and Evolution of Grid Connected to 5MW Solar Photovoltaic Plant in shivanasamudra", *International Journal of Research in Advent Technology*, Vol. 3, No. 1, June 2015
3. Alternative Energy Tutorials, Home of Alternative and Renewable Energy Tutorials. [www.alternative-energy-tutorials.com/energy-Articles/solar-cell-i-v-characteristic.html](http://www.alternative-energy-tutorials.com/energy-Articles/solar-cell-i-v-characteristic.html)
4. Pradhan Arjyadharal, Ali S. M., Jena Chitralkha, "Analysis of Solar PV Cell Performance With Changing Irradiance and Temperature", *International Journal of Engineering and Computer Science (IJECS)*, Vol. 2, issue 1, January2013
5. Jayanna Kanchikere & Kalyankumar, "Estimation of cost analysis for 5KW grid connected solar rooftop power plant - A case study", *International Journal of engineering science and computing*, vol 6, Issue 4, PP. 4505-4507, Apr 2016.
6. <https://eosweb.larc.nasa.gov/sse>.
7. B. Shiva Kumar, K. Sudhakar, "Performance evaluation of 10 MW grid connected solar photovoltaic power plant in India", *Energy Reports 1* (2015) 184–192
8. Trivedi, P., & Sharma, M. *Impact Of Green Production And Green Technology On Sustainability: Cases On Companies In India*.
9. Hemakshi Bhoje, Gaurang and Sharma, "An analysis of one MW photovoltaic solar power plant design", *International Journal of Advanced research in Electrical, Electronics and Instrumentation Engineering*, vol 3, Issue 1, PP 6969-6973, Jan2014.
10. Marion, B., Adelsten, J., Boyel, K., Hayden, H., Hammon, B., Fletcher, T., Canada, B., Narang, D., Kimber, A., Michell, L., Rich, G., Townsend, T., Detride, A., Kimbler, A., 2005. Performance parameters for grid-connected PV system In: *Proceeding of the 31st IEEE Photovoltaic Specialist Conference, Lake Buena Vista FL*, pp. 1601–1606
11. Ayompe, L. M., Duffy, A., McCormack, S. J., Conlon, M., 2011, Measured performance of a 1.72 kW rooftop grid connected photovoltaic system in Ireland. *Energy Convers. Manage.* 52, 816–825.

12. <http://sisifo.info>
13. Radhey S M, Jeetendra Singh Rathore and Shivani J, "Grid connected roof top solar power generation: A review", *International Journal of Engineering development and research*, vol 3, Issue 1, PP.325-330,2014.
14. M. H. Albadi, RS Alabri, MI masoud, KH Al Lawati, Al Ajmi, I A Farsi, "Design of 50KW solar PV roof top system", *International Journal of Smart Grid and Clean Energy*, vol 3, No.4, PP.41-409,2014